Investigation: Measuring the wavelength and speed of sound in free air

Apparatus

- double-beam oscilloscope
- audio-signal generator
- loudspeaker
- microphone
- connecting leads
- metre rule
- masking tape
- clamp and stand
- thermometer

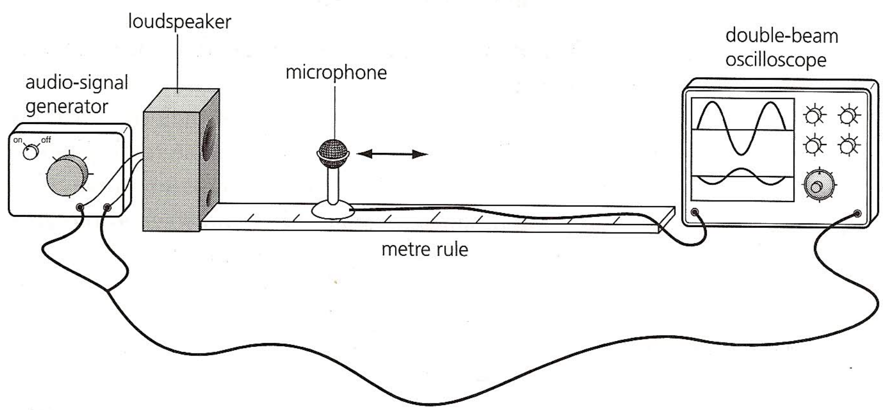

Figure 12.5

Plan

- Connect the microphone to one input of the oscilloscope and the audio-signal generator to the other.
- Connect the audio-signal generator to the loudspeaker.
- Tape a metre rule to the bench at right angles to the loudspeaker.
- Clamp the microphone to a stand, placed so that it can slide along the metre rule.
- Use the signal generator and loudspeaker to make a sound of about 5000 Hz and position the microphone to receive it.
- Adjust the oscilloscope controls until you have two waves on the screen – one from the microphone and the other from the signal generator.
- Check that as you move the microphone away from the loudspeaker, one trace moves relative to the other on the screen.
- Start with the microphone close to the loudspeaker and adjust its position until the traces on the screen line up. Record this position on the metre rule.
- Move the microphone away from the loudspeaker until the waves on the screen line up again. Use the wave traces to judge when you have moved the microphone exactly one wavelength through the sound wave. Continue to move the microphone through as many wavelengths as you can.
- Record the number of wavelengths moved through and record the microphone's new position.
- Measure the frequency of the waves as in the previous experiment.
- Record the air temperature.

Skill level (Implementing)

A: I was able to connect the apparatus together and get two wave traces on the oscilloscope without help. I chose an audio frequency that gave a strong signal from the microphone. I moved the microphone until the two wave traces were aligned. I moved the microphone an exact number of wavelengths and measured the distance moved. I measured the frequency of the sound wave.

All but one of the above = B; all but two = C; all but three = D; all but four = E.

Analysis

1 Put all of your measurements into a table (see the example in the *Sample readings* below).
2 Calculate a value for the wavelength of the sound.

Wave speed = frequency × wavelength

3 Calculate a value for the speed of sound in air.
4 Explain carefully why the length of the waves on the oscilloscope screen is not the wavelength of the sound: the trace represents a pressure/time graph of the wave as it passes the microphone.
5 Explain also why one trace moves relative to the other when you move the microphone through the sound wave in the air.

Sample readings Air temperature = 24 °C

first microphone position /mm	second microphone position /mm	distance moved /mm	number of wavelengths	wavelength /mm	frequency /Hz	speed /m s^{-1}
869	447	422	6	70.3	5200	366

Evaluation

This is a direct but not very precise way of measuring the speed of a travelling sound wave in free air. It is difficult to judge the two microphone positions exactly and there could be an uncertainty of 1 cm in each. When these are subtracted they give a smaller quantity with increased % uncertainty (2 cm in 70 cm or ~3%). Adding an uncertainty of 2% from the determination of the frequency (see p. 144) gives an overall uncertainty of ~5%.

Improving the plan

- Find the frequency that gives the largest signal from the microphone. Cheap microphones do not have flat responses and resonate at certain frequencies. A large signal from the microphone makes it possible to move through more wavelengths before the trace gets too small, and so reduces the uncertainty in this quantity.
- Use a frequency meter to measure the sound frequency.

Extension

To make this a full investigation, measure the wavelength and speed of the sound wave for different frequencies.